The Impact of a Weather Information System Display on General Aviation Pilot Workload and Performance

(or, "Can a GA pilot fly an aircraft and use a weather display at the same time?")

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Outline

- Background Information
- Purpose of Research
- Experiment Design and Protocol
- Test Facilities and Apparatus
- Experiment Tasks
- Results and Discussion
- Conclusions

Background

- 27% of GA accidents involve weather
- NASA's Aviation Safety Program
  - Reduce the aircraft accident rate by a factor of 5 within 10 years and by a factor of 10 within 25 years
- Aviation Weather Information (AWIN) program element
  - Provide improved weather information to users in the National Airspace System, and
  - Foster the use of this information to improve situation awareness and decision making

Cockpit Weather Information Systems (WIS)

- Data-linked cockpit WIS are being implemented to provide strategic en route information
- WIS displays can be used in GA airplane cockpits in a variety of positions and implementations
  - Panel-mounted
  - Tethered
  - Portable

Purpose of the Workload and Relative Position (WaRP) Experiment

- Investigate the effect of using a WIS display on pilot workload, flying proficiency, and weather information retrieval time and accuracy
  - With different flying tasks, and
  - With different display positions,
  - Compared to conventional means of obtaining weather information

Experiment Design

DISPLAY TYPE	FLIGHT TASK TYPE: VMC Task ("Low Workload")	FLIGHT TASK TYPE: IMC Task ("High Workload")
No Display ("Just Flying")	Condition 1	Condition 2
Radio ("Aural Display")	Condition 3	Condition 4
Panel WIS Display	Condition 5	Condition 6
Yoke WIS Display	Condition 7	Condition 8
Kneeboard WIS Display	Condition 9	Condition 10

- Same 10 participants assigned to each experimental cell
- Two replicates of each test condition

Dependent Measures

- Flight Path Parameter Deviation
  - Altitude, heading, and airspeed deviations (+ bank angle and vertical speed during the IMC Task)
- Subjective Assessments of Workload
  - Verbal reports using the Air Force Flight Test Center's Seven-Point Subjective Workload Estimate Scale
- Weather Information Retrieval Time and Accuracy

Participants

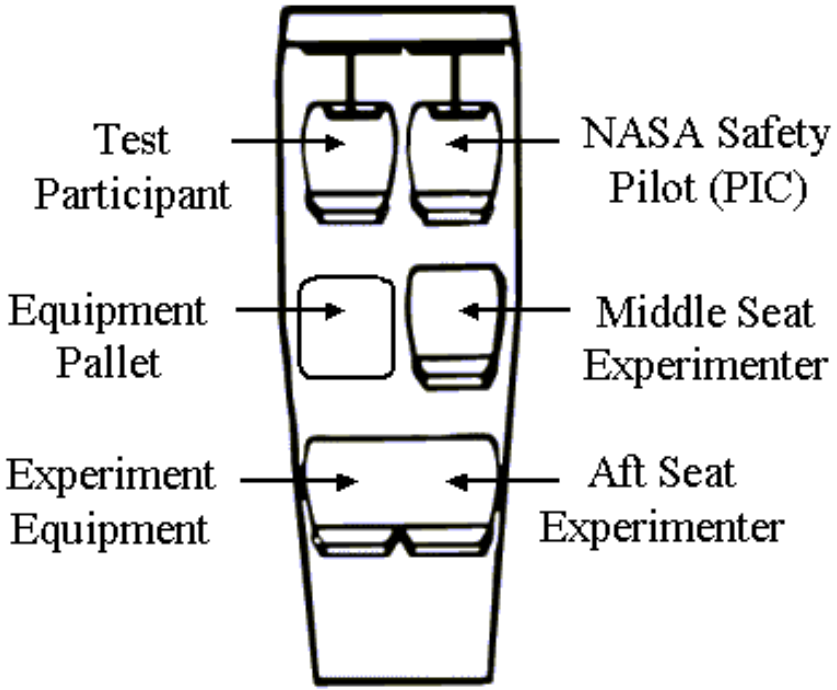
- 10 instrument rated GA pilots (5 private; 5 commercial)
- No CFIs
- Males ranging in age from 22 – 56
- On average, less than 500 total flight hours and approximately 30 hours during last 90 days
- No previous experience flying a C-206 or using an in-flight WIS display
- No previous experience flying for an air carrier or for the military

Experiment Protocol

Activity	Duration
Pre-Experimental Session	15 min
“Classroom” Training Session	1 hr
“In the Aircraft” Training Session	1 hr
Break and Flight Suit Fitting	30 min
Familiarization Flight	1.5 hrs
Lunch Break	1 hr
Pre-Flight Briefing	15 min
Experiment Flight	2.5 hrs
Break	15 min
Debriefing Session	30 min

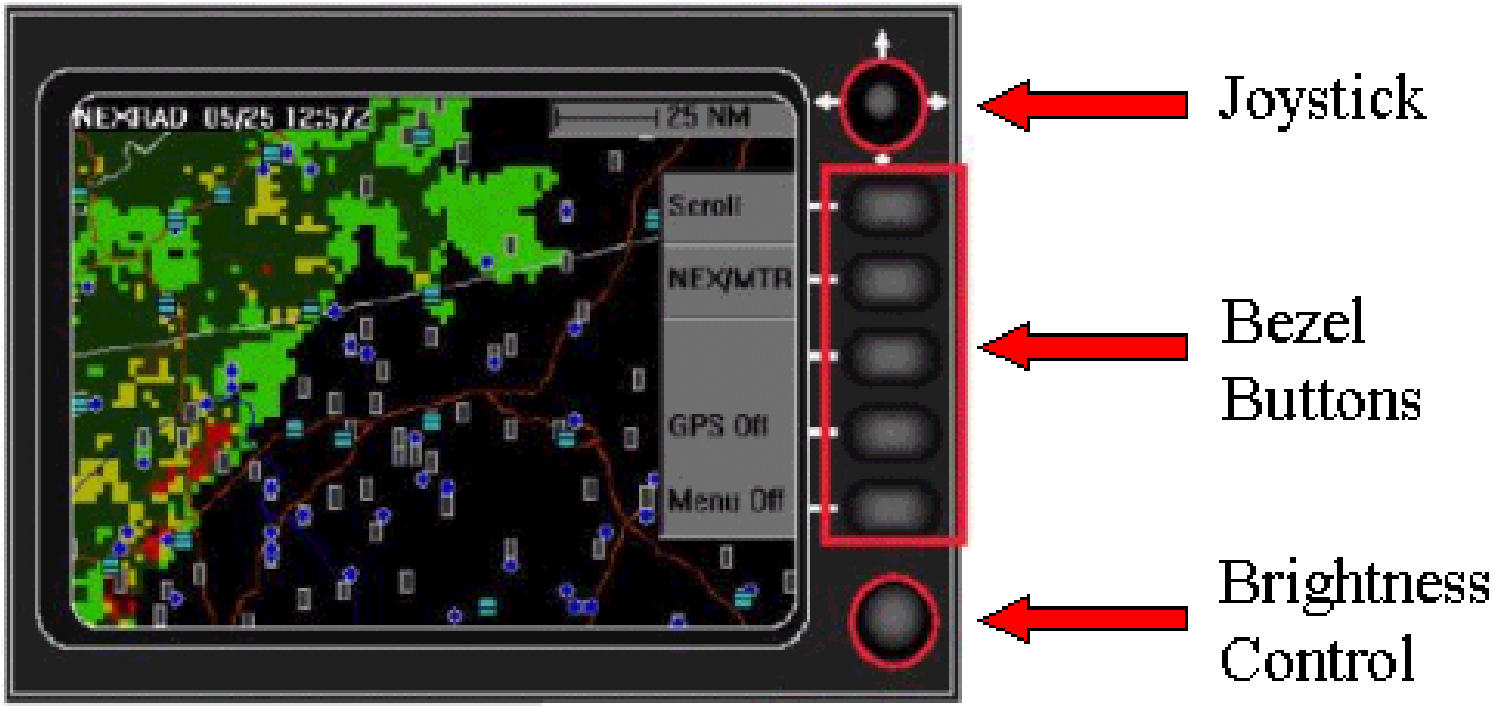
Test Airplane

- NASA LaRC's Cessna 206 (C-206)
  - High-wing, fixed gear, seats six
  - Constant-speed prop, 300 HP



Airborne WIS

- Prototype data-linked WIS system developed under a cooperative research agreement with NASA by NavRadio (now part of Honeywell / Bendix-King)



WIS Display Positions

PANEL
Representative of a permanently mounted display

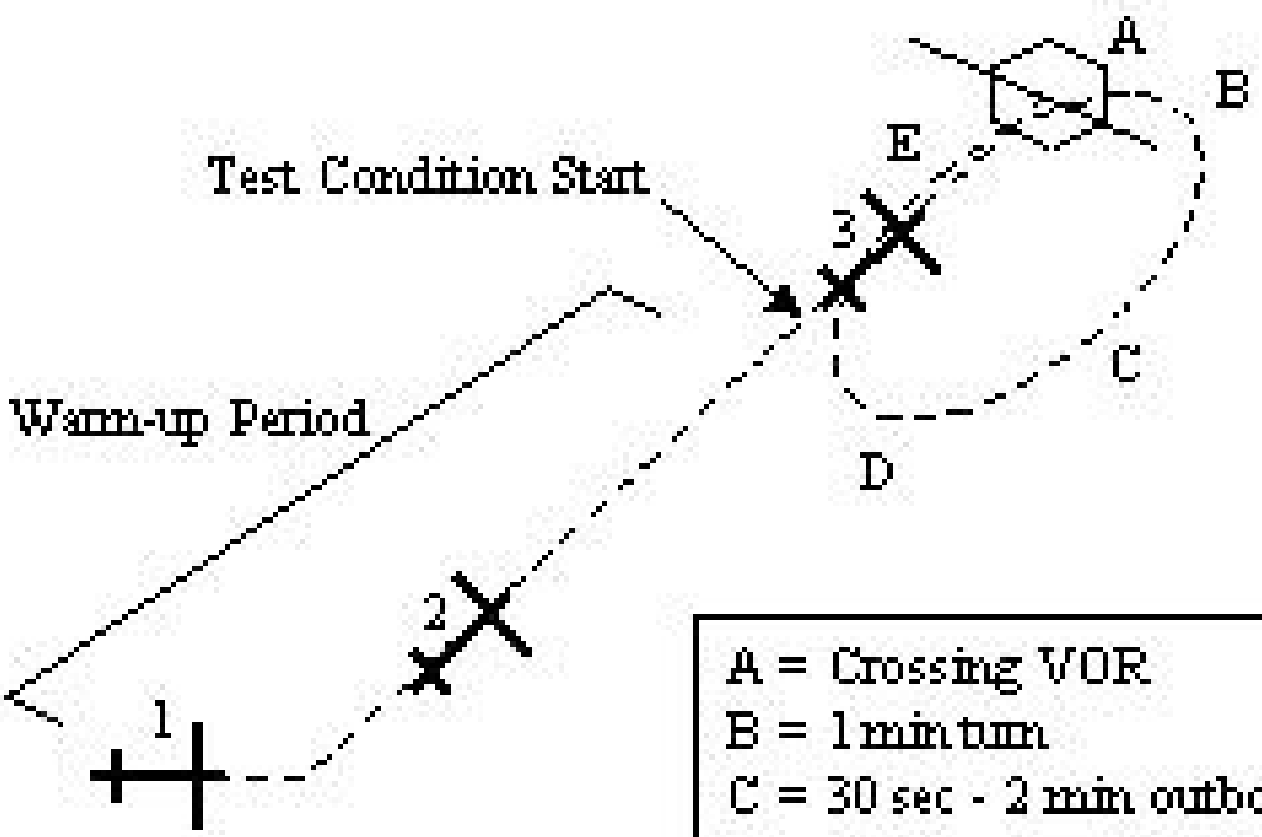
YOKE
Representative of a portable display "within scan"

KNEEBOARD
Representative of a portable display "outside of scan"

Flight Tasks

- VMC Task
  - Low workload environment in visual conditions
  - Assigned heading, altitude, and airspeed
- IMC Task
  - High workload environment in simulated instrument conditions
  - Holding pattern with descents

IMC Task

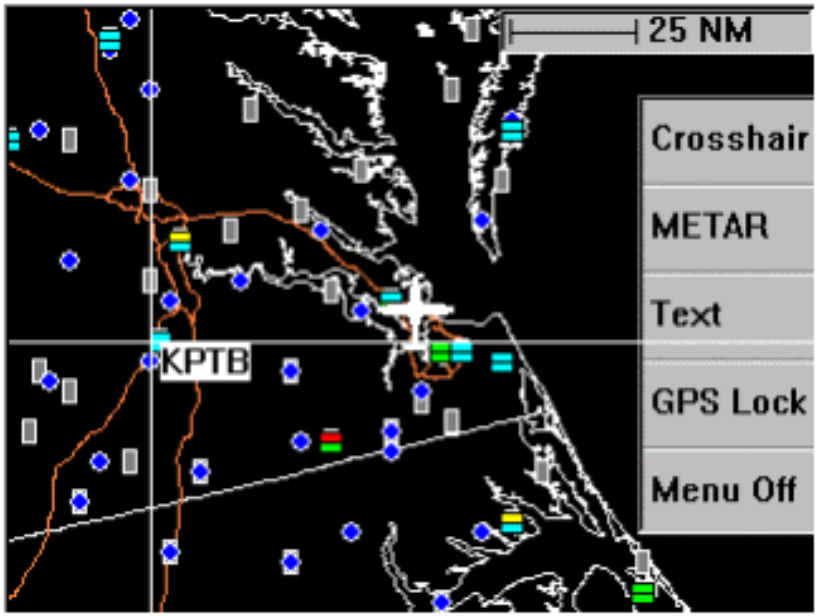


A = Crossing VOR
B = 1 min turn
C = 30 sec - 2 min outbound leg
D = 1 min turn
E = 1 min inbound leg

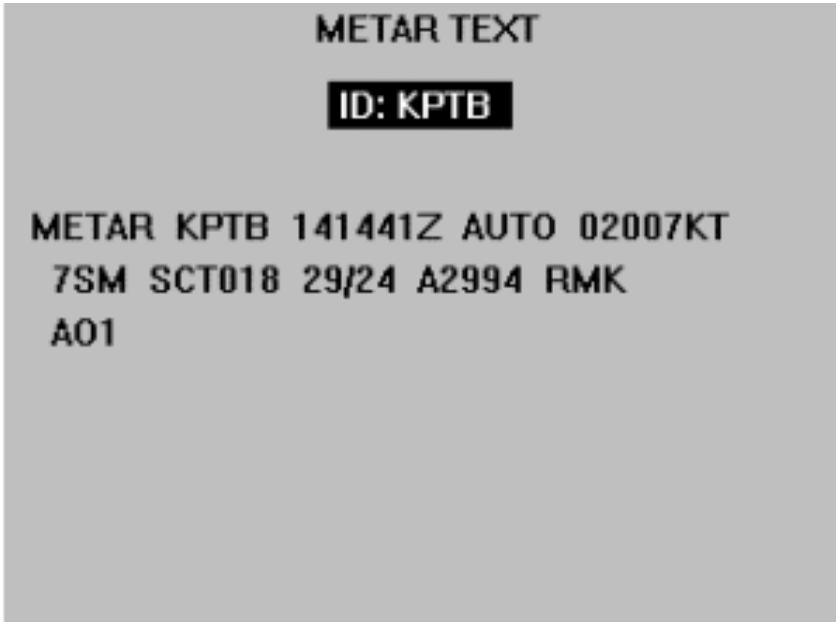
Weather Information Acquisition Tasks

- Radio
  - Look up ASOS/AWOS frequency on chart
  - Tune radio and copy automated weather report
- WIS Display
  - Locate reporting station on moving map
  - Select station and display METAR text

In-Flight Use of WIS Display



Selection of METAR reporting station

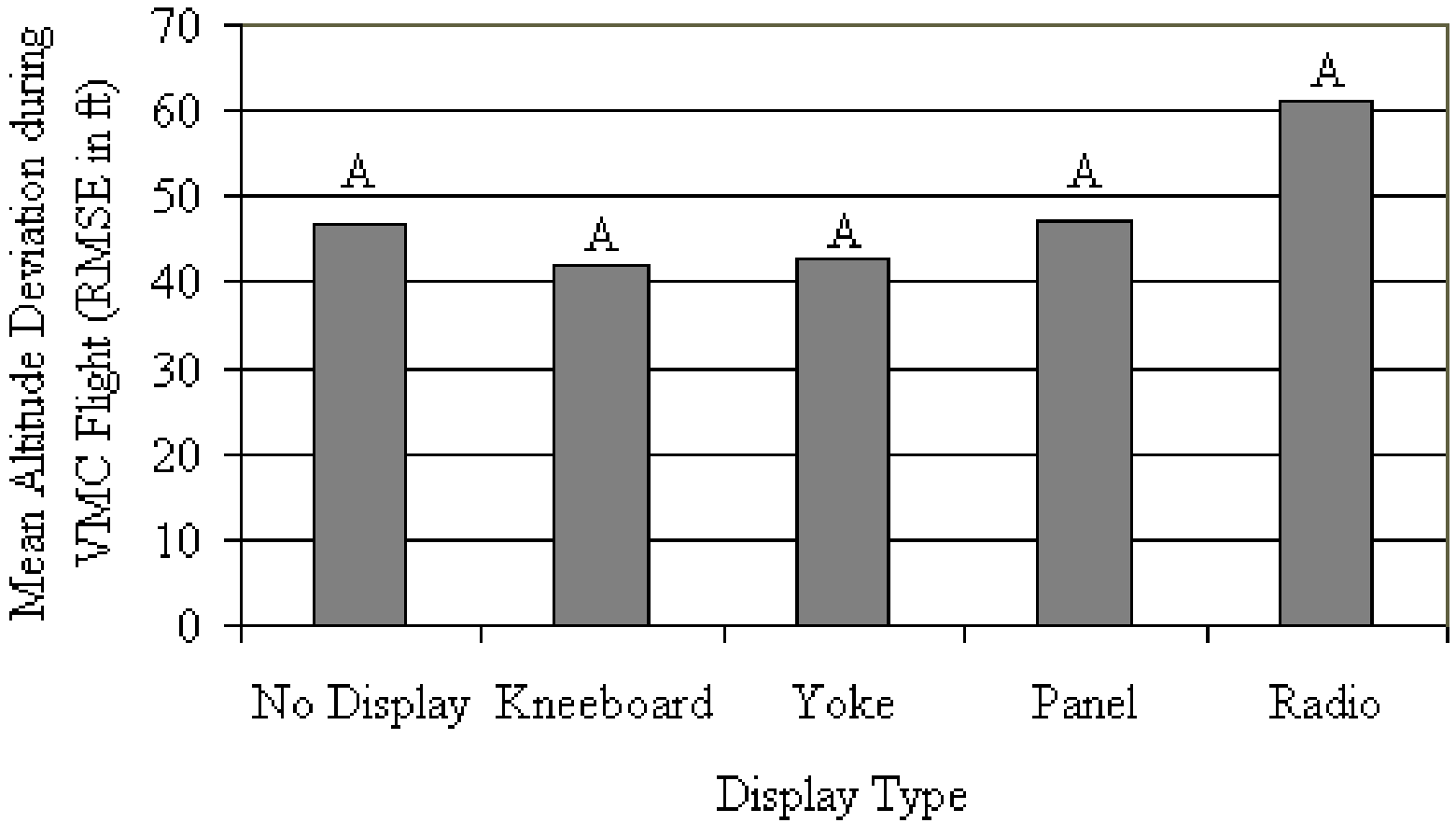


METAR text screen

Results

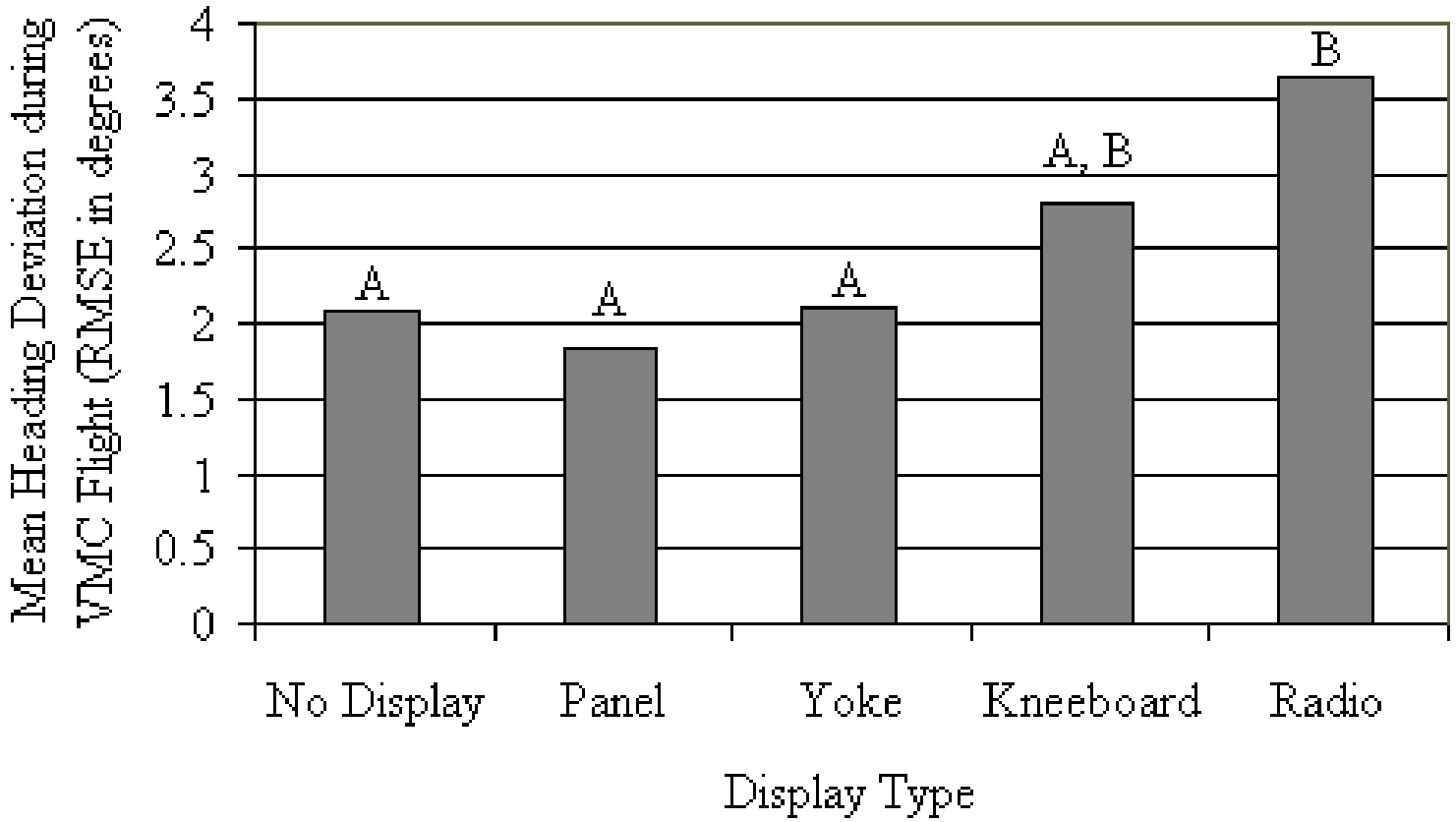
- Flight path parameter deviation
  - Preliminary results from the VMC Task
- Subjective assessments of workload, weather information retrieval time, and weather information retrieval accuracy
  - Flight Task Type
  - Display Type
  - Display Type x Flight Task Type

Altitude Deviation



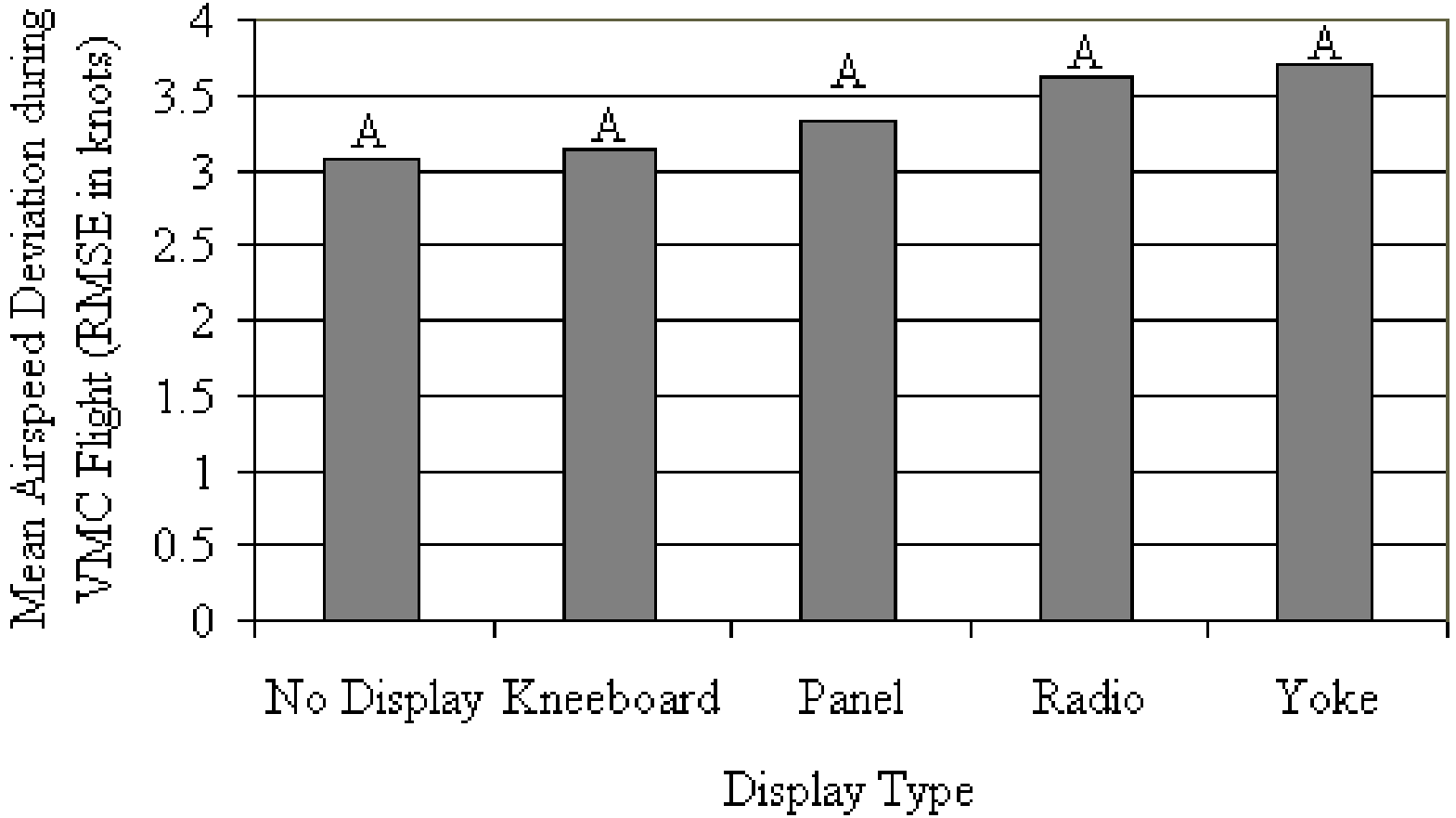
- Statistically, the same magnitude of altitude deviations occurred during each test condition

Heading Deviation



- Greater heading deviations occurred when participants used the Radio than when they were “Just Flying,” or when they used either the Panel or Yoke WIS Display

Airspeed Deviation

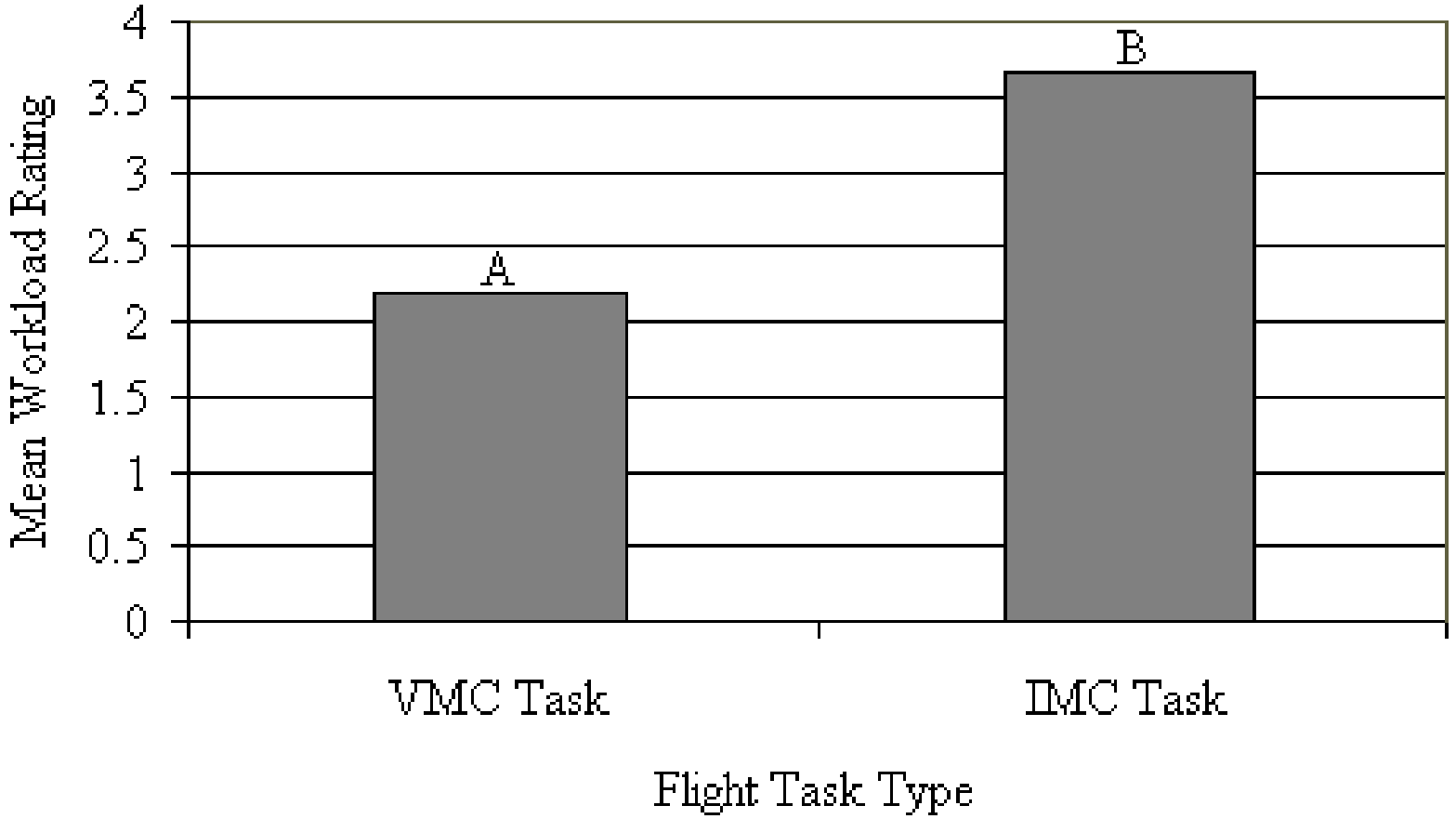


- Statistically, the same magnitude of airspeed deviations occurred during each test condition

Discussion: Flight Path Parameter Deviation (VMC Task)

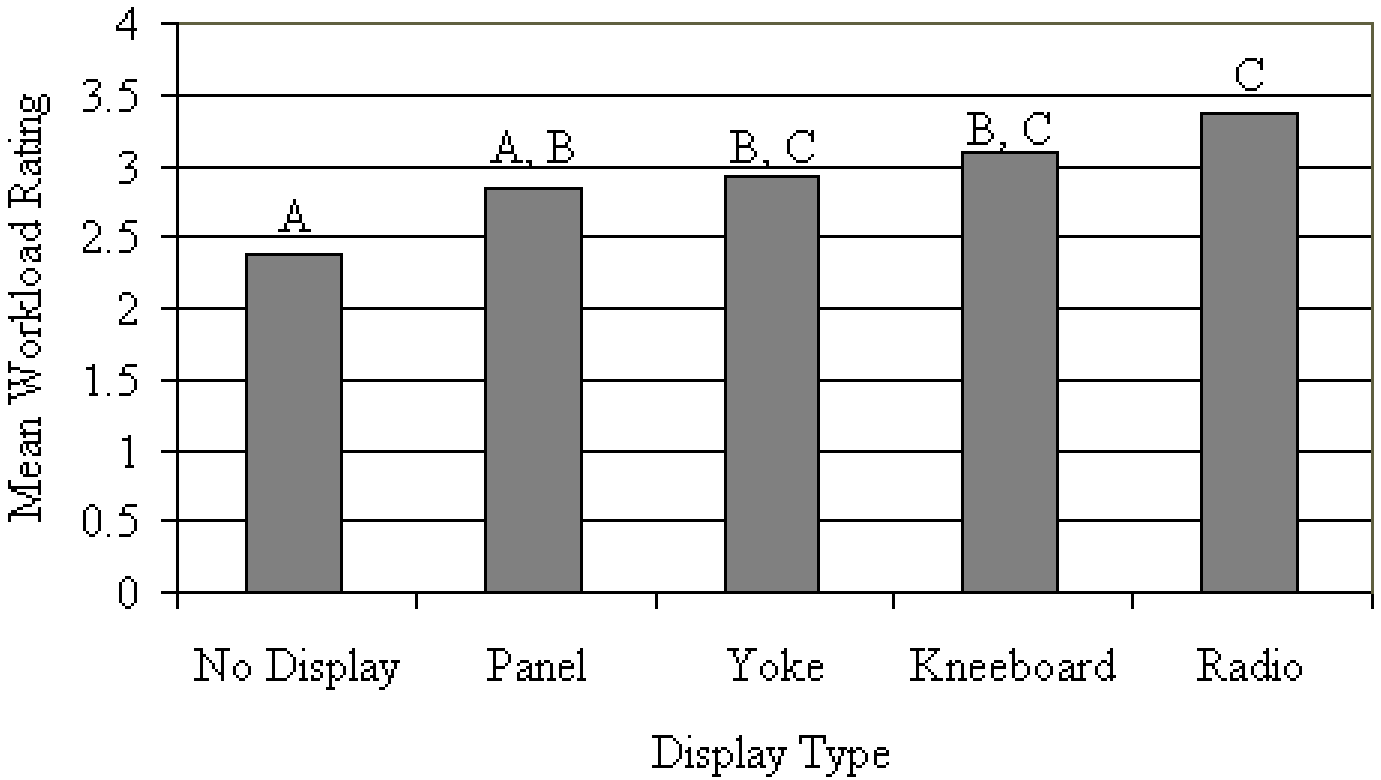
- RMSE values were within the FAA's Practical Test Standards for the Instrument Rating
- Smallest heading deviations occurred when the WIS display was located within the instrument scan area

Workload Ratings: Flight Task Type



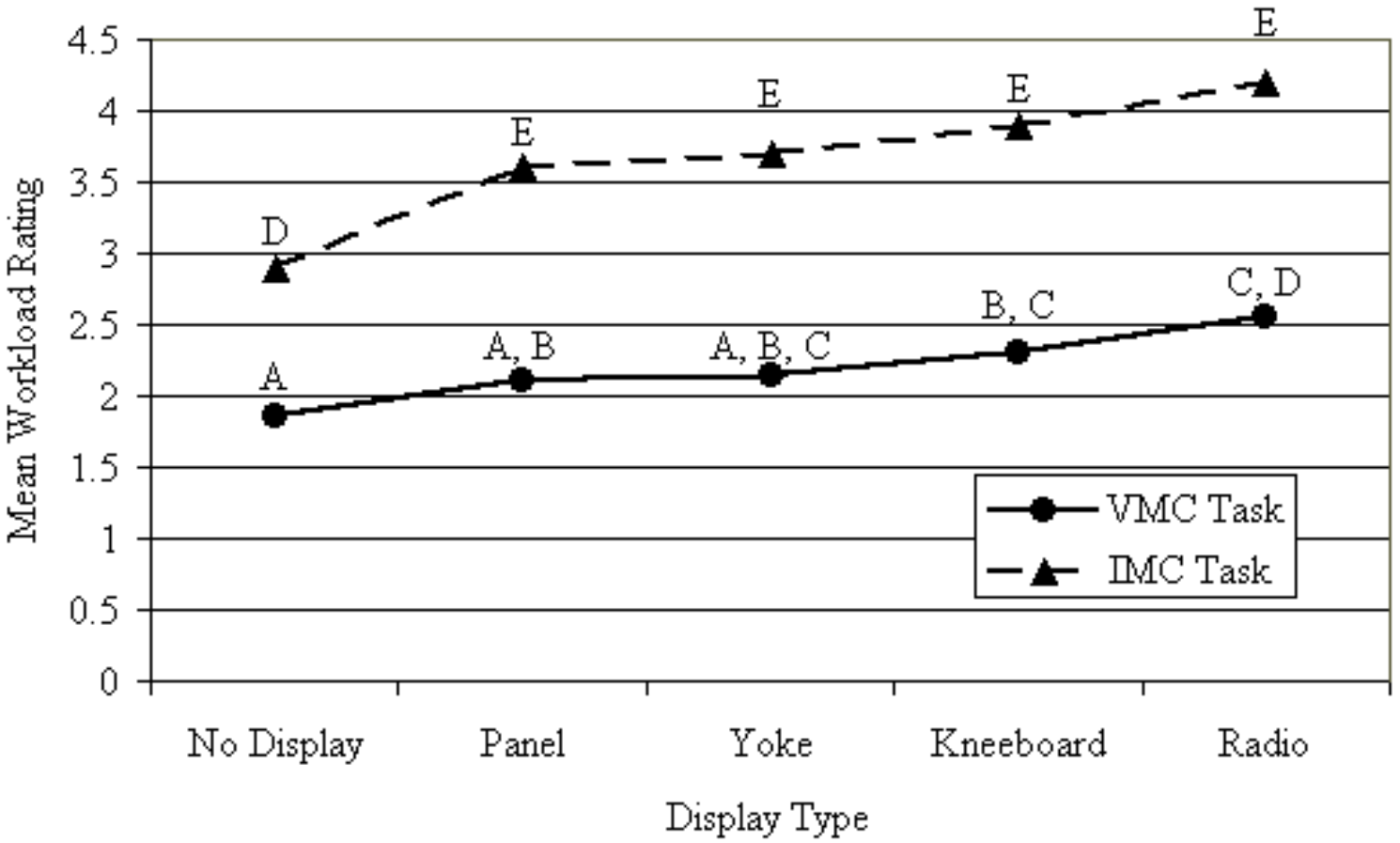
- VMC Task < IMC Task

Workload Ratings: Display Type



- No Display = Panel WIS Display < Radio
- Panel WIS Display = Yoke WIS Display = Kneeboard WIS Display

Workload Ratings: Display Type x Flight Task Type

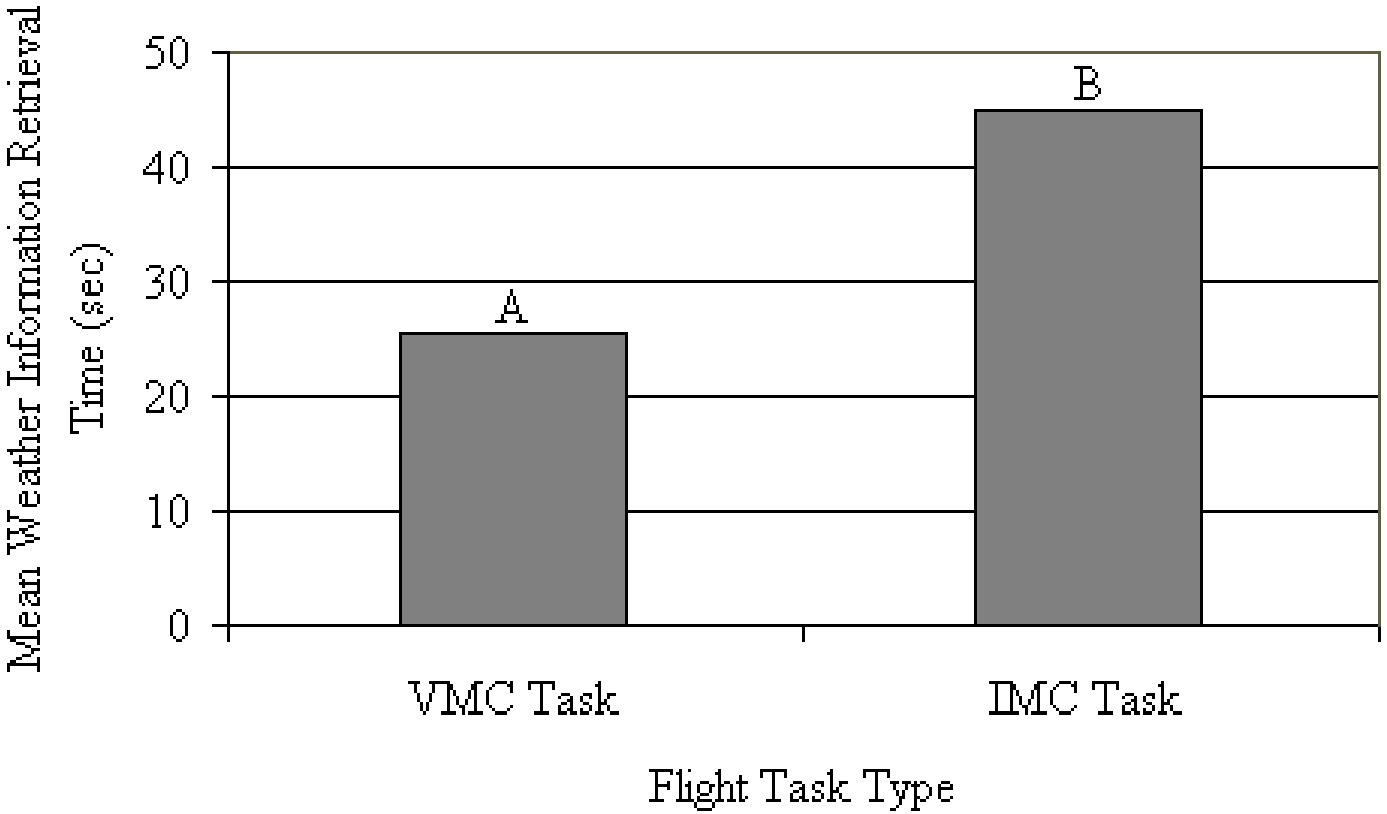


- WIS Display always ≤ Radio during the same task

Discussion: Subjective Assessments of Workload

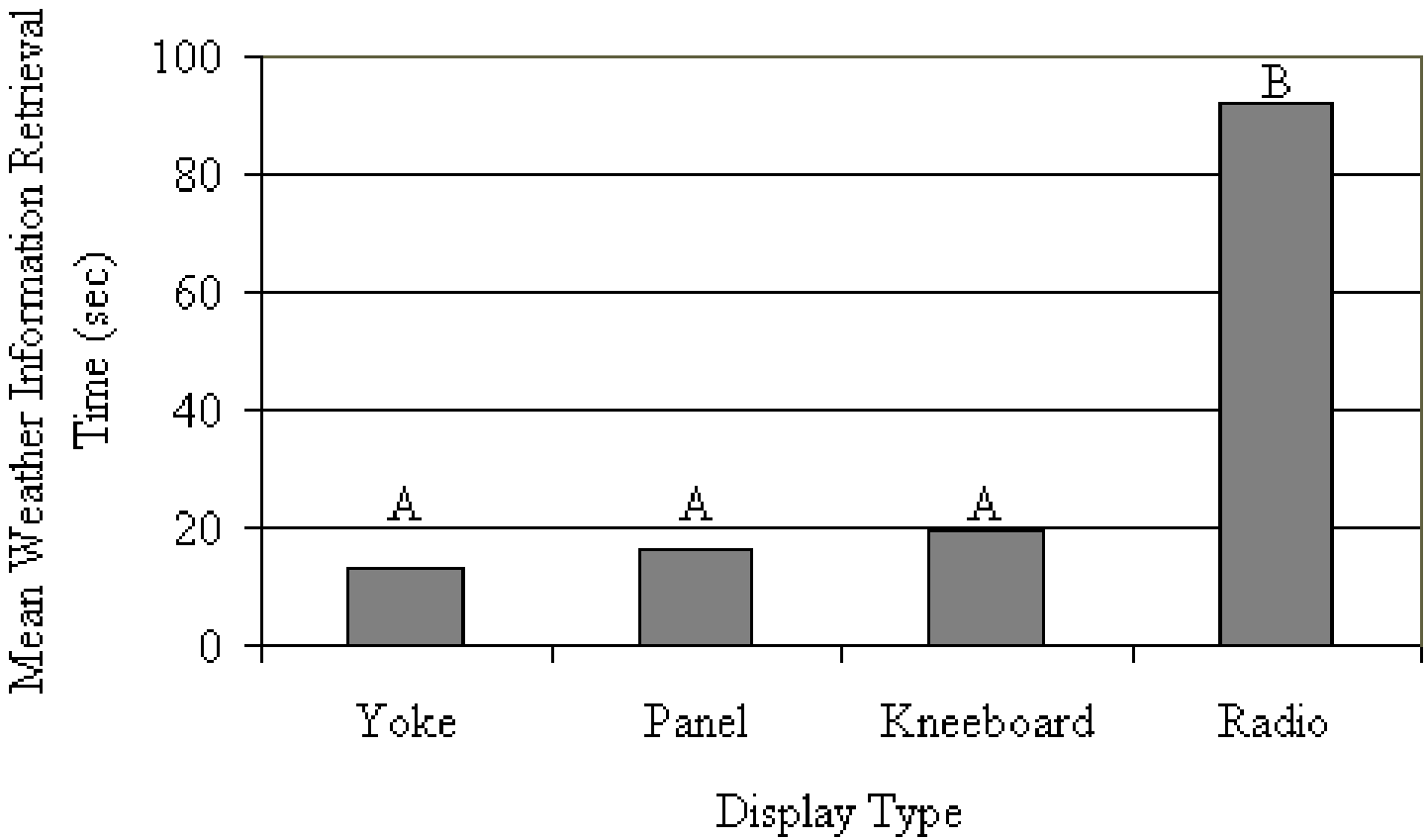
- Higher mean workload ratings for the IMC Task, regardless of display type
- Lower mean workload ratings for the WIS Display than for the Radio, within a given flight task type
- Panel WIS Display < Yoke WIS Display < Kneeboard WIS Display
  - Lower workload by keeping portable WIS displays within the instrument scan area

Weather Information Retrieval Time: Flight Task Type



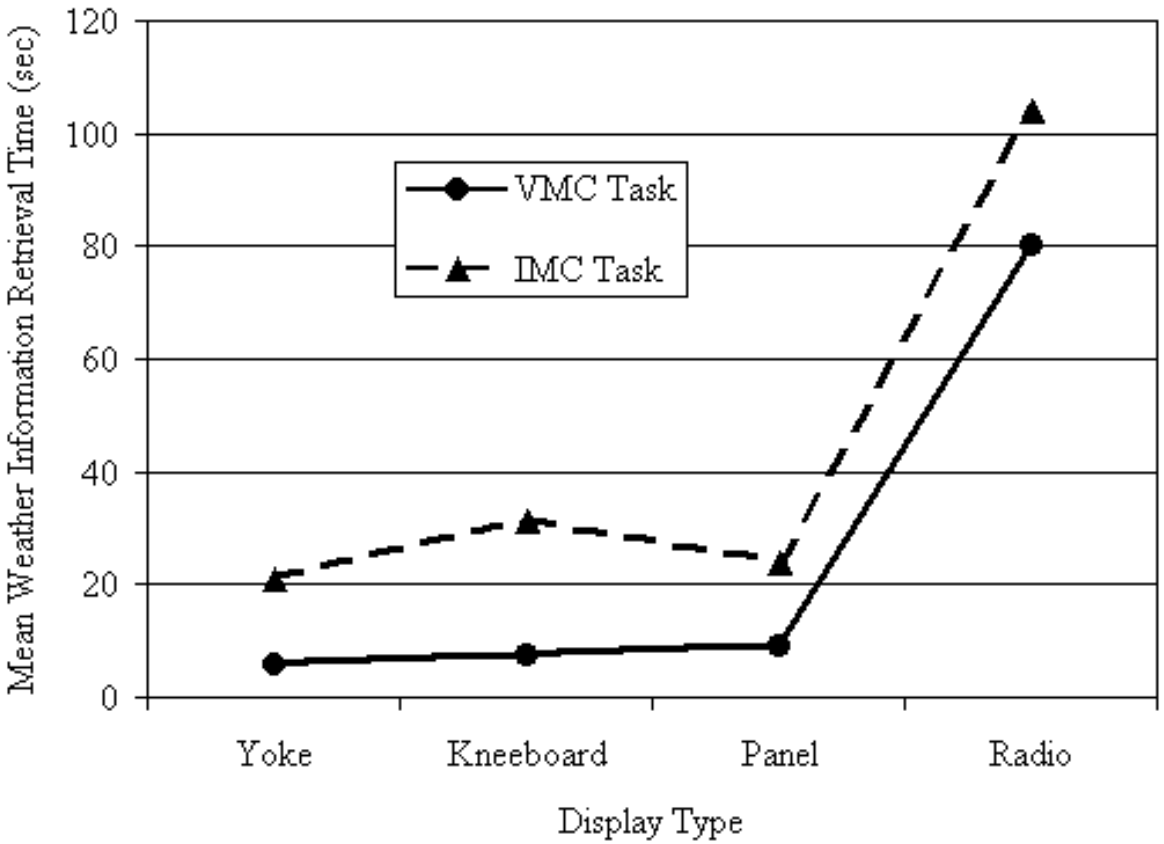
- VMC Task < IMC Task

Weather Information Retrieval Time: Display Type



- WIS Display << Radio

Weather Information Retrieval Time: Display Type x Flight Task Type

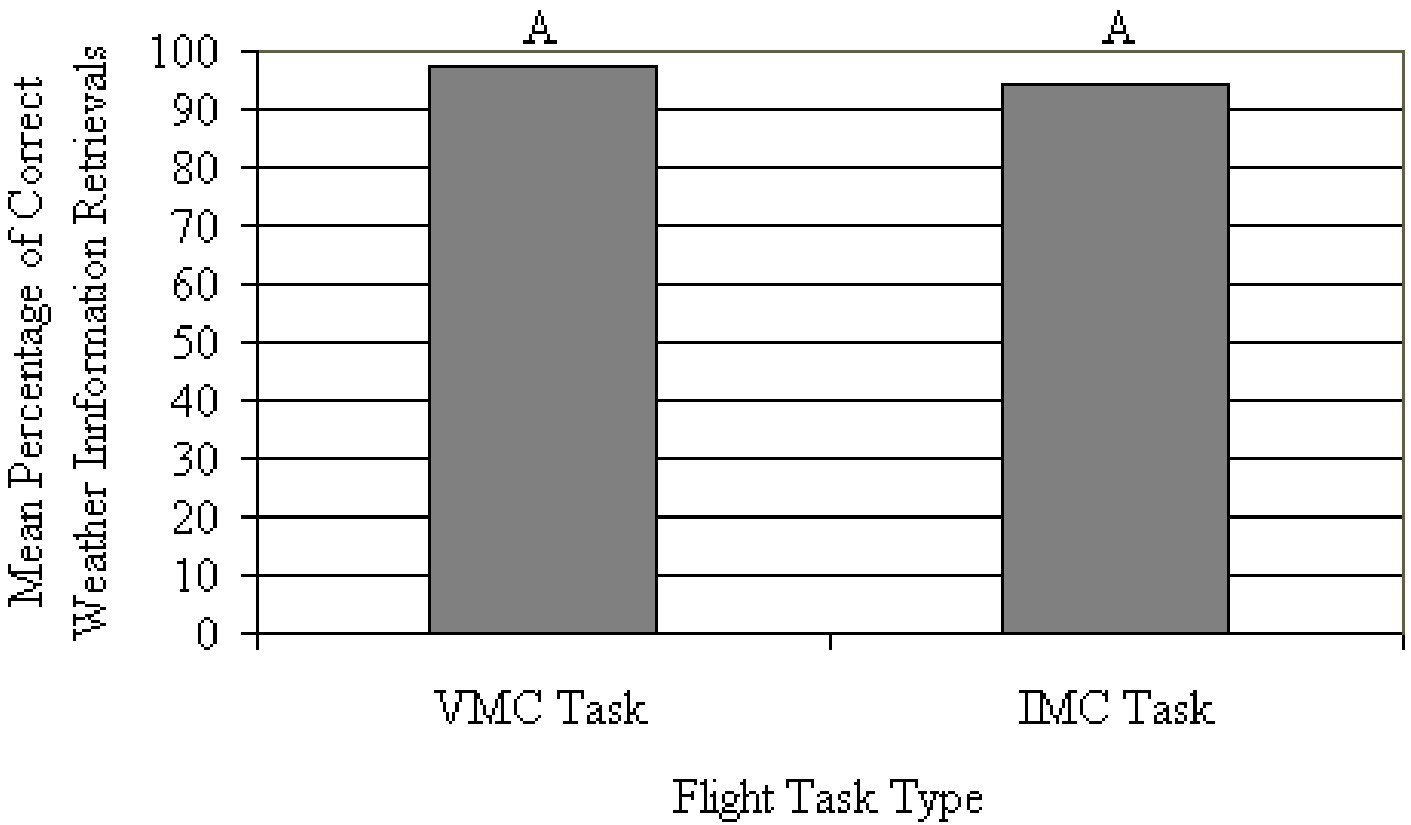


- WIS Display always << Radio regardless of task type

Discussion: Weather Information Retrieval Time

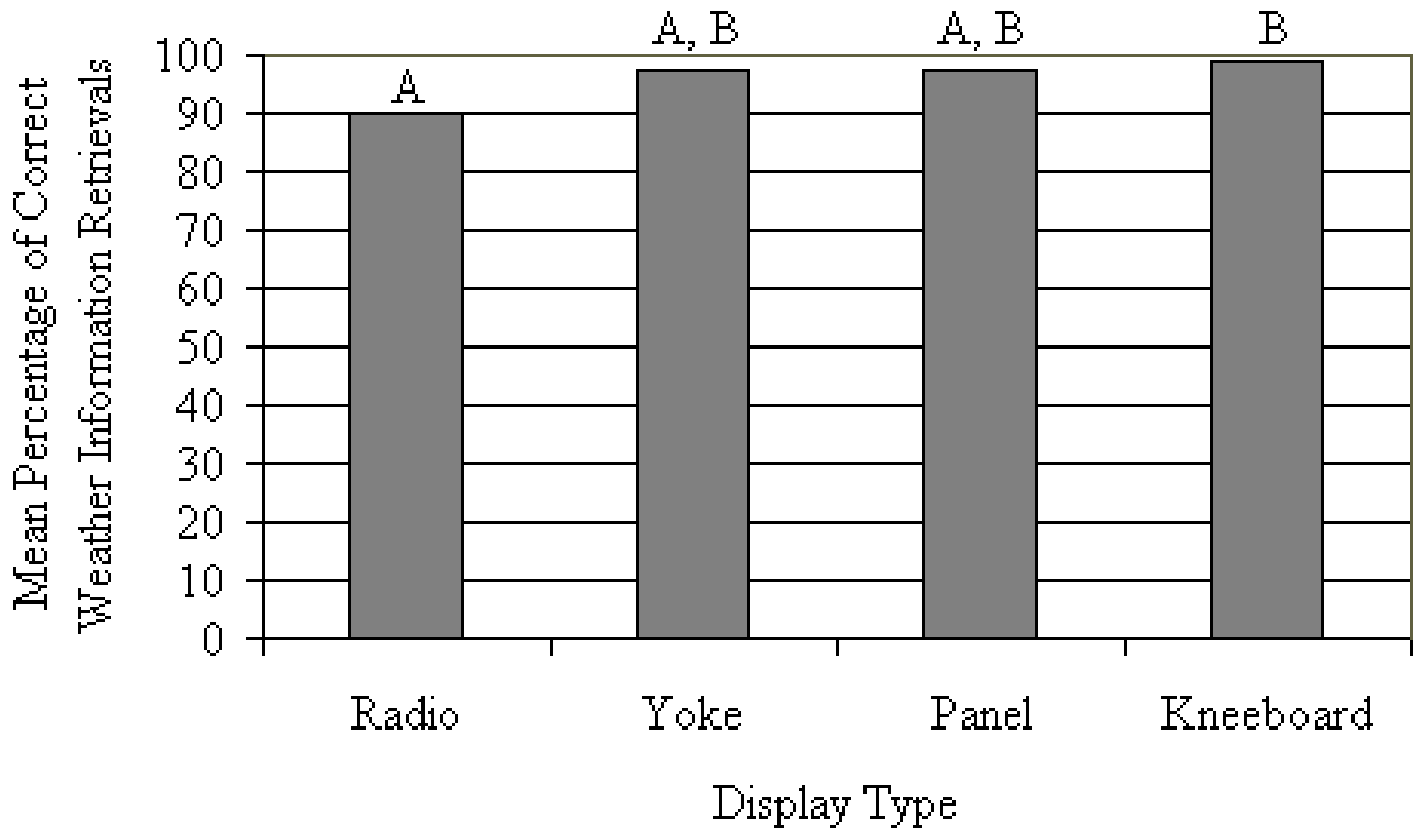
- Participants took 75% longer to retrieve weather information during the IMC Task, regardless of display type
- Participants retrieved weather information more than four times faster with a WIS Display
- Faster retrieval times with a WIS Display can:
  - Result in improved situation awareness for pilots
  - Equate to pilots having more time to devote to other important flight tasks

Weather Information Retrieval Accuracy: Flight Task Type



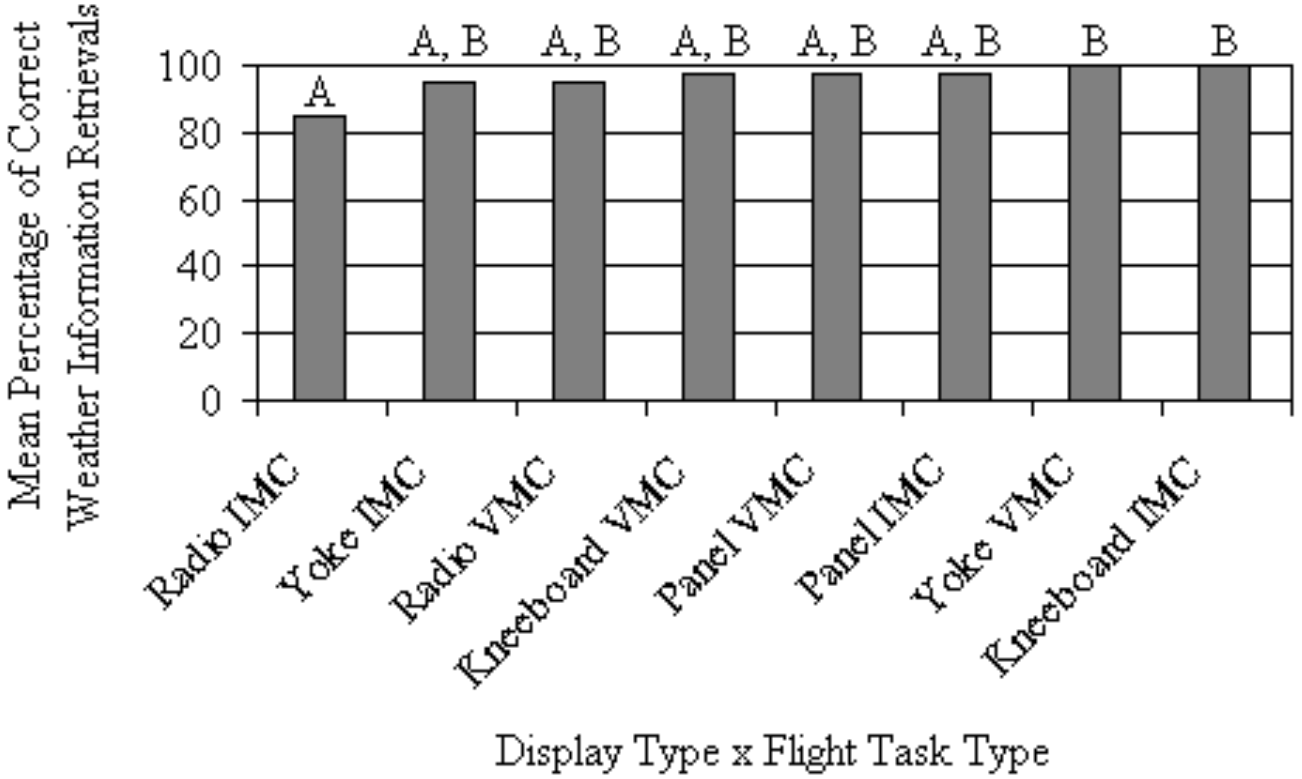
- VMC Task = IMC Task

Weather Information Retrieval Accuracy: Display Type



- Radio < Kneeboard WIS Display

Weather Information Retrieval Accuracy: Display Type x Flight Task Type



- Radio / IMC < Yoke WIS Display / VMC = Kneeboard WIS Display / IMC

Discussion: Weather Information Retrieval Accuracy

- Mean accuracy levels of 95% or higher occurred during all but one test condition (i.e., Radio / IMC = 85%)
- Slightly lower overall accuracy levels were achieved during the IMC Task
- Mean accuracy levels were slightly higher with the WIS Display (in all positions) than with the Radio
- Weak support that weather information retrieval accuracy is slightly better with a WIS Display than with the Radio, especially in high-workload flying situations

Conclusions

- GA pilots' use of a WIS Display facilitates:
  - Smaller flight path parameter deviations
  - Lower workload level
  - Much quicker information retrieval
  - Slightly better retrieval accuracy
- Overall, pilots are able to fly and simultaneously access weather information slightly better when the WIS Display is located within the instrument scan area
- Use of the WIS Display did not increase workload when compared to the current method of retrieving weather information via the Radio

Backup Slides

C-206 Cockpit

Subjective Workload Estimate Scale

1 = Nothing to do; No system demands
2 = Light activity; Minimum demands
3 = Moderate activity; Easily managed; Considerable spare time
4 = Busy; Challenging but manageable; Adequate time available
5 = Very busy; Demanding to manage; Barely enough time
6 = Extremely busy; Very difficult; Non-essential tasks postponed
7 = Overloaded; System unmanageable; Essential tasks undone; Unsafe